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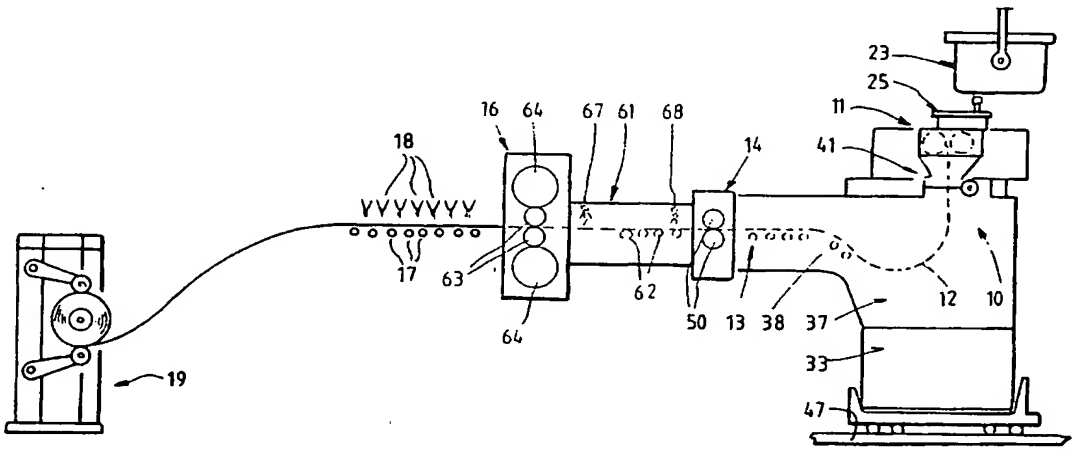
(54) Title: CASTING STEEL STRIP



(57) Abstract: A twin roll caster (11) produces thin steel strip (12) which passes through a first enclosure (37) to a pinch roll stand (14) including pinch rolls (50) through which the strip passes into a second enclosure (61). The strip passes horizontally through enclosure (61) to an in-line hot rolling mill (16) which closes the exit end of enclosure (61) and hot rolls the strip as it exits that enclosure. Enclosures (37) and (61) are sealed against ingress of atmospheric air and both maintain oxygen levels less than the surrounding atmosphere to reduce formation of scale on the strip. The second chamber (61) is fitted with water spray nozzles (67, 68) operable to spray fine mist of water droplets onto the upper face of the strip as it passes through that enclosure thereby to generate steam producing a superatmospheric pressure within the enclosure preventing ingress of atmospheric air.

WO 01/39914 A1

CASTING STEEL STRIP

TECHNICAL FIELD

This invention relates to continuous casting of steel strip in a strip caster, particularly a twin roll caster.

In a twin roll caster molten metal is introduced between a pair of contra-rotated horizontal casting rolls which are cooled so that metal shells solidify on the moving roll surfaces and are brought together at the nip between them to produce a solidified strip product delivered downwardly from the nip between the rolls. The term "nip" is used herein to refer to the general region at which the rolls are closest together. The molten metal may be poured from a ladle into a smaller vessel from which it flows through a metal delivery nozzle located above the nip so as to direct it into the nip between the rolls, so forming a casting pool of molten metal supported on the casting surfaces of the rolls immediately above the nip and extending along the length of the nip. This casting pool is usually confined between side plates or dams held in sliding engagement with end surfaces of the rolls so as to dam the two ends of the casting pool against outflow, although alternative means such as electromagnetic barriers have also been proposed.

When casting steel strip in a twin roll caster, the strip leaves the nip at very high temperatures of the order of 1400°C and it suffers very rapid scaling due to oxidation at such high temperatures. Such scaling results in a significant loss of steel product. For example, 3% of a 1.55 mm thick strip (typical scale thickness 35 microns) can be lost from oxidation as the strip cools. Moreover, it results in the need to descale the strip prior to further processing to avoid surface quality problems such as rolled-in scale and this causes significant extra complexity and cost. For example, the hot strip material may be passed directly to a rolling mill in line with the

strip caster and thence to a run out table on which it is cooled to coiling temperature before it is coiled. However scaling of the hot strip material emerging from the strip caster progresses so rapidly that it becomes necessary to install descaling equipment to descale the material immediately before it enters the in line rolling mill. Even in cases when the strip is cooled to coiling temperature without hot rolling, it will generally be necessary to descale the strip either before it is coiled or in a later processing step.

To deal with the problem of rapid scaling of strip emerging from a twin roll strip caster it has been proposed to enclose the newly formed strip within a sealed enclosure, or a succession of such enclosures, in which a controlled atmosphere is maintained in order to inhibit oxidation of the strip. The controlled atmosphere can be produced by charging the sealed enclosure or successive enclosures with non-oxidising gases. Such gases can be inert gases such as nitrogen or argon or exhaust gases from fuel burners.

United States Patent 5,762,126 discloses an alternative relatively cheap and energy efficient way of limiting exposure of the high temperature strip to oxygen. The strip is caused to pass through an enclosed space from which it extracts oxygen by the formation of scale and which is sealed so as to control the ingress of oxygen containing atmosphere whereby to control the extent of scale formation. In this method of operation, it is possible to rapidly reach a steady state condition in which scale formation is brought to low levels without the need to deliver a non-oxidising or reducing gas into the enclosure.

We have now determined that a substantially non-oxidising atmosphere can be cheaply and effectively produced within an enclosure for the hot steel strip by introducing water in a fine mist spray to generate steam within the enclosure. The steam generation greatly

increases the gaseous volume within the enclosure so as to produce a superatmospheric pressure which substantially prevents the ingress of atmospheric air. It can also produce an increased level of hydrogen gas within the enclosure to significantly reduce the oxygen level in the enclosure and retard the rate of oxidation of the strip. Since the casting rolls cannot be exposed to water or steam without risking catastrophic disturbance of the casting pool, it is necessary to isolate the enclosure in which steam is generated from the cooling rolls.

DISCLOSURE OF THE INVENTION

According to the invention there is provided a method of continuously casting steel strip comprising:

supporting a casting pool of molten steel on one or more chilled casting surfaces;

moving the chilled casting surface or surfaces to produce a solidified steel strip moving away from the casting pool;

guiding the solidified strip successively through first and second enclosures as it moves away from the casting pool;

sealing the first and second enclosures to restrict ingress of atmospheric air; and

introducing water into the second enclosure in the form of fine mist to generate steam within the second enclosure and thereby to produce a superatmospheric pressure in that enclosure substantially excluding ingress of atmospheric air.

The strip may exit the first chamber at a temperature in the range 1300°C to 1150°C, preferably about 1220°C.

The first chamber should be of sufficient length to minimise the possibility of migration of water vapour into the region immediately below the casting rolls.

Preferably, the water is introduced through one or more fine mist sprays directed onto a face of the steel

strip as it passes through the second enclosure.

More specifically, the water is preferably introduced through one or more mist sprays directed downwardly onto the upper face of the steel strip.

In order to produce the spray mist, water may be forcibly propelled by a gas propellant through one or more mist spray nozzles.

Preferably, the gas propellant is an inert gas, for example nitrogen.

Preferably further, the introduction of the water spray mist into the second enclosure produces an increased level of hydrogen gas therein.

The strip may be passed from the first enclosure to the second enclosure through a pair of pinch rolls. In that case the pinch rolls may be operated to reduce the strip thickness by up to 5%, and preferably of the order of 2%.

The first and second enclosures may initially be purged with an inert gas, for example nitrogen, before commencement of casting of said strip so as to reduce the initial oxygen content within the enclosures. Such purging may for example reduce the initial content within the enclosures to between 5% to 10%.

During casting of said strip the first enclosure may be continuously charged with an inert gas, for example nitrogen. Alternatively, the oxygen content in the first enclosure may be maintained at a level less than the surrounding atmosphere by continuous oxidation of the strip passing there through in the manner disclosed in United States Patent 5,762,126.

The invention further provides apparatus for casting steel strip comprising:

a pair of generally horizontal casting rolls forming a nip between them;

metal delivery means to deliver molten steel into the nip between the casting rolls to form a casting pool of molten steel supported on the rolls;

means to chill the casting rolls;

means to rotate the casting rolls in mutually opposite directions whereby to produce a cast strip delivered downwardly from the nip;

strip guide means to guide the strip delivered downwardly from the nip through a transit path which takes it away from the nip;

a first enclosure to confine the strip throughout said transit path which enclosure is sealed to control ingress of atmospheric air;

a second enclosure to receive strip after it has passed through the first enclosure which second enclosure is also sealed to control ingress of atmospheric air; and

water spray means operable to spray water into the second enclosure in the form of a fine mist so as to generate steam within the second enclosure.

Preferably, the water spray means comprises one or more water mist spray nozzles mounted within the second enclosure and operable to spray water mist onto the upper face of steel strip.

In a preferred method according to the invention, the solidified steel strip is delivered to a hot rolling mill in which it is hot rolled as it is produced.

The strip may exit the second enclosure before entering the rolling mill and in this case the enclosure may comprise a pair of pinch rolls between which the strip passes to exit the enclosure. However, it is preferred that the strip remain within the second enclosure at its entry into the rolling mill. This may be achieved by sealing the second enclosure against rolls or a housing of the rolling mill.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be more fully explained one particular embodiment will be described in detail with reference to the accompanying drawings in which:

Figure 1 is a vertical cross-section through a steel strip casting and rolling installation constructed and operated in accordance with the present invention;

Figure 2 illustrates essential components of a twin roll caster incorporated in the installation and including a first hot strip enclosure;

Figure 3 is a vertical cross-section through the twin roll caster;

Figure 4 is a cross-section through end parts of the caster;

Figure 5 is a cross-section on the line 5-5 in Figure 4;

Figure 6 is a view on the line 6-6 in Figure 4; and

Figure 7 illustrates a section of the installation downstream from the caster which includes a second strip enclosure and an in-line rolling mill.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The illustrated casting and rolling installation comprises a twin roll caster denoted generally as 11 that produces a cast steel strip 12 which passes in a transit path 10 across a guide table 13 to a pinch roll stand 14. After exiting the pinch roll stand 14, the strip passes to a hot rolling mill 16 in which it is hot rolled to reduce its thickness. The thus rolled strip exits the rolling mill and passes to a run out table 17 on which it may be force cooled by water jets 18 and thence to a coiler 19.

Twin roll caster 11 comprises a main machine frame 21 which supports a pair of parallel casting rolls 22 having casting surfaces 22A. Molten metal is supplied during a casting operation from a ladle 23 through a refractory ladle outlet shroud 24 to a tundish 25 and thence through a metal delivery nozzle 26 into the nip 27 between the casting rolls 22. Hot metal thus delivered to the nip 27 forms a pool 30 above the nip and this pool is confined at the ends of the rolls by a pair of side closure

dams or plates 28 which are applied to stepped ends of the rolls by a pair of thrusters 31 comprising hydraulic cylinder units 32 connected to side plate holders 28A. The upper surface of pool 30 (generally referred to as the "meniscus" level) may rise above the lower end of the delivery nozzle so that the lower end of the delivery nozzle is immersed within this pool.

Casting rolls 22 are water cooled so that shells solidify on the moving roller surfaces and are brought together at the nip 27 between them to produce the solidified strip 12 which is delivered downwardly from the nip between the rolls.

At the start of a casting operation a short length of imperfect strip is produced as the casting conditions stabilise. After continuous casting is established, the casting rolls are moved apart slightly and then brought together again to cause this leading end of the strip to break away in the manner described in Australian Patent Application 27036/92 so as to form a clean head end of the following cast strip. The imperfect material drops into a scrap box 33 located beneath caster 11 and at this time a swinging apron 34 which normally hangs downwardly from a pivot 35 to one side of the caster outlet is swung across the caster outlet to guide the clean end of the cast strip onto the guide table 13 which feeds it to the pinch roll stand 14. Apron 34 is then retracted back to its hanging position to allow the strip 12 to hang in a loop beneath the caster before it passes to the guide table 13 where it engages a succession of guide rollers 36.

The twin roll caster may be of the kind which is illustrated and described in some detail in granted Australian Patents 631728 and 637548 and United States Patents 5,184,668 and 5,277,243 and reference may be made to those patents for appropriate constructional details which form no part of the present invention.

Between the casting rolls and pinch roll stand 14, the newly formed steel strip is enclosed within a first

enclosure denoted generally as 37 defining a sealed space 38. Enclosure 37 is formed by a number of separate wall sections which fit together at various seal connections to form a continuous enclosure wall. These comprise a wall section 41 which is formed at the twin roll caster to enclose the casting rolls and a wall section 42 which extends downwardly beneath wall section 41 to engage the upper edges of scrap box 33 when the scrap box is in its operative position so that the scrap box becomes part of the enclosure. The scrap box and enclosure wall section 42 may be connected by a seal 43 formed by a ceramic fibre rope fitted into a groove in the upper edge of the scrap box and engaging flat sealing gasket 44 fitted to the lower end of wall section 42. Scrap box 33 may be mounted on a carriage 45 fitted with wheels 46 which run on rails 47 whereby the scrap box can be moved after a casting operation to a scrap discharge position. Screw jack units 40 are operable to lift the scrap box from carriage 45 when it is in the operative position so that it is pushed upwardly against the enclosure wall section 42 and compresses the seal 43. After a casting operation the jack units 40 are released to lower the scrap box onto carriage 45 to enable it to be moved to scrap discharge position.

Enclosure 37 further comprises a wall section 48 disposed about the guide table 13 and connected to the frame 49 of pinch roll stand 14 which includes a pair of pinch rolls 50 against which the enclosure is sealed by sliding seals 60. Accordingly, the strip exits the enclosure 38 by passing between the pair of pinch rolls 50 and it passes immediately into a second enclosure denoted generally as 61 through which the strip passes to the hot rolling mill 15.

Most of the enclosure wall sections may be lined with fire brick and the scrap box 33 may be lined either with fire brick or with a castable refractory lining. Alternatively, all or parts of the enclosure wall may be formed by water cooled metal panels.

The enclosure wall section 41 which surrounds the casting rolls is formed with side plates 51 provided with notches 52 shaped to snugly receive the side dam plate holders 28A when the side dam plates 28 are pressed against the ends of the rolls by the cylinder units 32. The interfaces between the side plate holders 28A and the enclosure side wall sections 51 are sealed by sliding seals 53 to maintain sealing of the enclosure. Seals 53 may be formed of ceramic fibre rope.

The cylinder units 32 extend outwardly through the enclosure wall section 41 and at these locations the enclosure is sealed by sealing plates 54 fitted to the cylinder units so as to engage with the enclosure wall section 41 when the cylinder units are actuated to press the side plates against the ends of the rolls. Thrusters 31 also move refractory slides 55 which are moved by the actuation of the cylinder units 32 to close slots 56 in the top of the enclosure through which the side plates are initially inserted into the enclosure and into the holders 28A for application to the rolls. The top of the enclosure is closed by the tundish, the side plate holders 28A and the slides 55 when the cylinder units are actuated to apply the side dam plates against the rolls. In this way the complete enclosure 37 is sealed prior to a casting operation to establish the sealed space 38.

The second strip enclosure 61 serves an extension of the first enclosure 37 in which the strip can be held in an atmosphere up to the hot rolling mill 16 which contains a series of pass line rollers 62 to guide strip horizontally through the enclosure to the work rolls 63 of rolling mill 16 which are disposed between two larger backing rolls 64. Enclosure 61 is sealed at one end against pinch rolls 50 by sliding seals 65 and at its other end it is sealed against the working rolls 63 of rolling mill 16 by sliding seals 66. The sliding seals 65, 66 could be replaced by rotary sealing rolls to run or the strip in the vicinity of the pinch rolls and reduction

rolls respectively.

Enclosure 61 is fitted with a pair of water spray nozzles 67, 68 which are each operable to spray a fine mist of water droplets downwardly onto the upper face of the steel strip as it passes through the enclosure. Spray nozzle 67 is mounted in the roof of enclosure 61 immediately downstream from the pinch roll stand 14. Nozzle 68 is located at the other end of enclosure 61 immediately in advance of the rolling mill 16. The nozzles may be standard commercially available mist spray nozzles operable with a gas propellant to produce a fine spray of water. In the method of the present invention the gas propellant may be an inert gas such as nitrogen. In a typical installation the nozzles will be operated under nitrogen at a pressure of around 400 kPa. The water may be supplied at around 100-500 kPa pressure, although the pressure of the water is not critical. The nozzles are set up to produce a flat spray across the width of the strip.

In operation of the illustrated caster, both of the enclosures 37 and 61 may initially be purged with nitrogen gas prior to commencement of casting. Immediately prior to casting, the water sprays are activated so that as soon as the hot strip passes through chamber 61 steam is generated within that chamber so as to produce a superatmospheric pressure preventing ingress of atmospheric air. During casting the first enclosure 37 may continue to be supplied with nitrogen so as to maintain a substantially inert atmosphere. Alternatively, the supply of nitrogen may be terminated after commencement of casting. Initially the strip will take up all of the oxygen from the enclosure space 38 to form heavy scale on the strip. However, the sealing of space 38 controls the ingress of oxygen containing atmosphere below the amount of oxygen that could be taken up by the strip. Thus, after an initial start up period the oxygen content in the enclosure space 38 will remain depleted so limiting the availability of oxygen for oxidation of the strip. In this way, the formation of

scale is controlled without the need to maintain a supply of nitrogen to the enclosure space 38.

A twin roll casting and rolling installation as illustrated in the drawings has been operated extensively and testing has been carried out with and without the operation of the water mist sprays 67, 68. Gas sampling of the atmosphere within chamber 61 has shown that operation of the water sprays produces a marked reduction in oxygen content and a very significant increase in hydrogen content as illustrated by the following results:

	Cast 2M0o23 (No mist Spray)	Cast 2M0o26 (Mist Spray)
Hydrogen	0.03%	2.8%
Oxygen	3.95%	2.1%
Argon	0.25%	0.1%
Nitrogen	95.7%	94.9%
Methane	Not Detected	Not Detected
Carbon Monoxide	<0.01%	0.01%
Carbon Dioxide	0.03%	0.01%

The greatly increased level of hydrogen within enclosure 61 and the associated marked reduction in oxygen content dramatically reduces scale formation. This increased hydrogen level may be explained by cracking or conversion of water molecules under the high temperature conditions within the enclosure. It is thought that oxygen is taken from water molecules into the strip by oxidation during initial passage of the strip through the enclosure so as to generate a significant quantity of hydrogen. Subsequent oxidation of the strip is suppressed by the hydrogen and the superatmospheric pressure within the chamber which limits ingress of atmospheric air, but is sufficient to maintain the hydrogen content in the enclosure and to produce a very thin layer of scale on the strip which has been found to be desirable on hot rolling to avoid sticking in the roll bite. It has been found that

the very thin layer of scale produced in the extremely moist atmosphere in enclosure 61 saves as a strongly adherent lubricant which minimises roll wear and operational difficulties at the rolling mill.

CLAIMS:

1. A method of continuously casting steel strip comprising:

supporting a casting pool of molten steel on one or more chilled casting surfaces;

moving the chilled casting surface or surfaces to produce a solidified steel strip moving away from the casting pool;

guiding the solidified strip successively through first and second enclosures as it moves away from the casting pool;

sealing the first and second enclosures to restrict ingress of atmospheric air; and

introducing water into the second enclosure in the form of fine mist to generate steam within the second enclosure and thereby to produce a superatmospheric pressure in that enclosure substantially excluding ingress of atmospheric air.

2. A method as claimed in claim 1, wherein the strip exits the first chamber at a temperature in the range 1300°C to 1150°C.

3. A method as claimed in claim 1 or claim 2, wherein the water is introduced through one or more fine mist sprays directed onto a face of the steel strip as it passes through the second enclosure.

4. A method as claimed in claim 3, wherein the water is introduced through one or more mist sprays directed downwardly onto the upper face of the steel strip.

5. A method as claimed in any one of claims 1 to 4, wherein in order to produce the spray mist, water is forcibly propelled by a gas propellant through one or more mist spray nozzles.

6. A method as claimed in claim 5, wherein the gas propellant is an inert gas.

7. A method as claimed in claim 6, wherein the gas propellant is nitrogen.

8. A method as claimed in any one of claims 1 to 7, wherein the introduction of the water spray mist into the second enclosure produces an increased level of hydrogen gas therein.

9. A method as claimed in any one of claims 1 to 8, wherein the strip is passed from the first enclosure to the second enclosure through a pair of pinch rolls.

10. A method as claimed in claim 9, wherein the pinch rolls are operated to reduce the strip thickness by up to 5%.

11. A method as claimed in any one of claims 1 to 10, wherein the first and second enclosures are initially purged with an inert gas before commencement of casting of said strip so as to reduce the initial oxygen content within the enclosures.

12. A method as claimed in claim 11, wherein the purging reduces the initial oxygen content within the enclosures to between 5% to 10%.

13. A method as claimed in claim 11 or claim 12, wherein the purging gas is nitrogen.

14. A method as claimed in any one of claims 11 to 13, wherein during casting of said strip the first enclosure is continuously charged with inert gas.

15. A method as claimed in any one of claims 11 to 13, wherein during casting of said strip the oxygen content in the first enclosure is maintained at a level less than the surrounding atmosphere by continuous oxidation of the strip passing therethrough.

16. A method as claimed in any one of claims 1 to 15, wherein the solidified strip is delivered to a hot rolling mill in which it is hot rolled as it is produced.

17. A method as claimed in claim 16, wherein the hot rolling mill is disposed at the exit to the second enclosure and seals that enclosure so as to hot roll the strip as it exits the second enclosure.

18. Apparatus for casting steel strip comprising:

a pair of generally horizontal casting rolls

forming a nip between them;

metal delivery means to deliver molten steel into the nip between the casting rolls to form a casting pool of molten steel supported on the rolls;

means to chill the casting rolls;

means to rotate the casting rolls in mutually opposite directions whereby to produce a cast strip delivered downwardly from the nip;

strip guide means to guide the strip delivered downwardly from the nip through a transit path which takes it away from the nip;

a first enclosure to confine the strip throughout said transit path which enclosure is sealed to control ingress of atmospheric air;

a second enclosure to receive strip after it has passed through the first enclosure which second enclosure is also sealed to control ingress of atmospheric air; and

water spray means operable to spray water into the second enclosure in the form of a fine mist so as to generate steam within the second enclosure.

19. Apparatus as claimed in claim 18, wherein the water spray means comprises one or more water mist spray nozzles mounted within the second enclosure.

20. Apparatus as claimed in claim 19, wherein the spray nozzles are disposed so as to spray water mist onto an upper face of the steel strip.

21. Apparatus as claimed in any one of claims 18 to 20, wherein the first and second enclosures are divided from one another by a pair of pinch rolls.

22. Apparatus as claimed in claim 21, wherein the pinch rolls are operable to reduce the strip thickness.

23. Apparatus as claimed in any one of claims 18 to 22, and further comprising a hot rolling mill disposed so as to hot roll the strip as it is produced.

24. Apparatus as claimed in claim 23, wherein the hot rolling mill is disposed at the exit to the second enclosure and seals that enclosure so as to hot roll the strip as it exits the second enclosure.

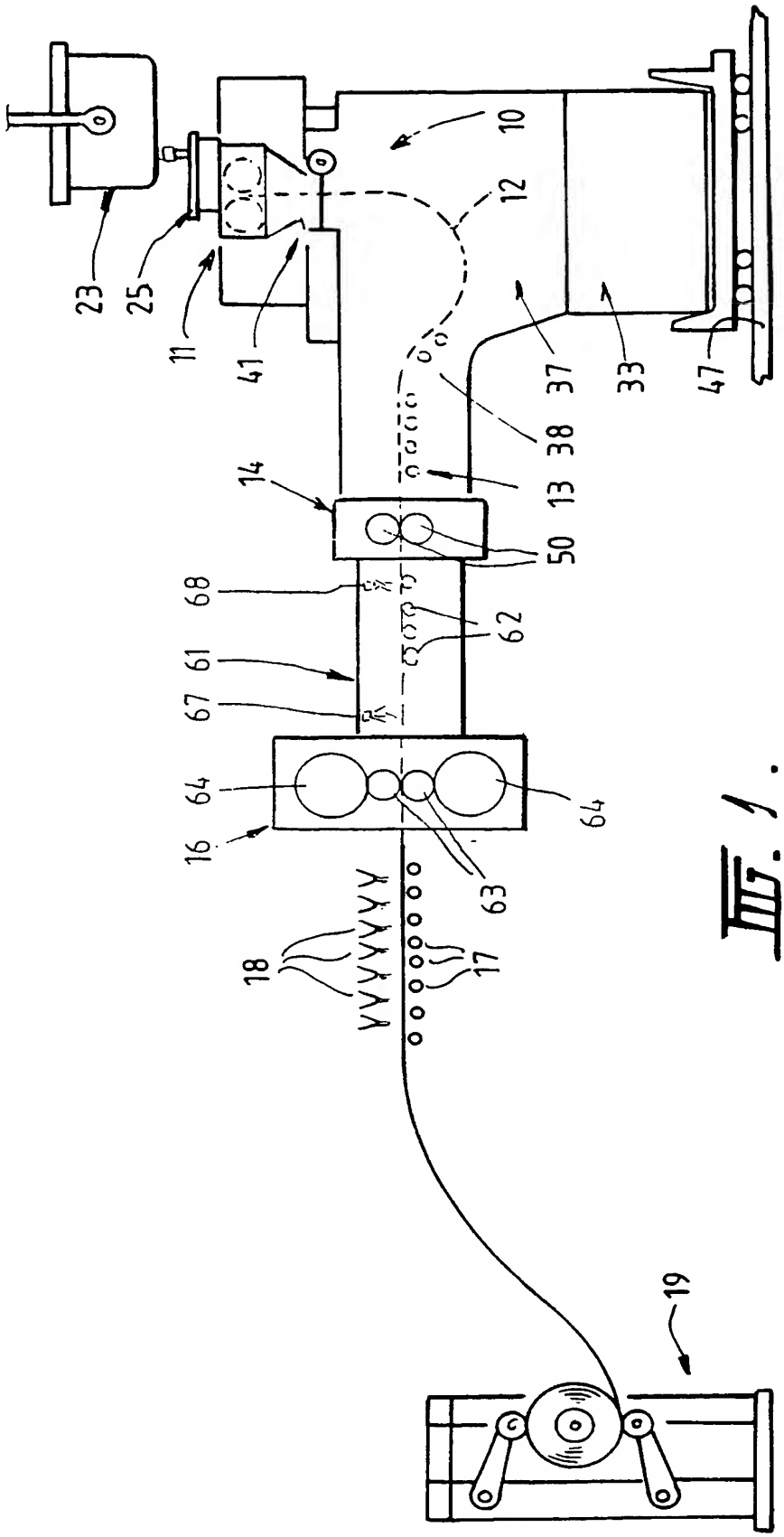


Fig. 1.

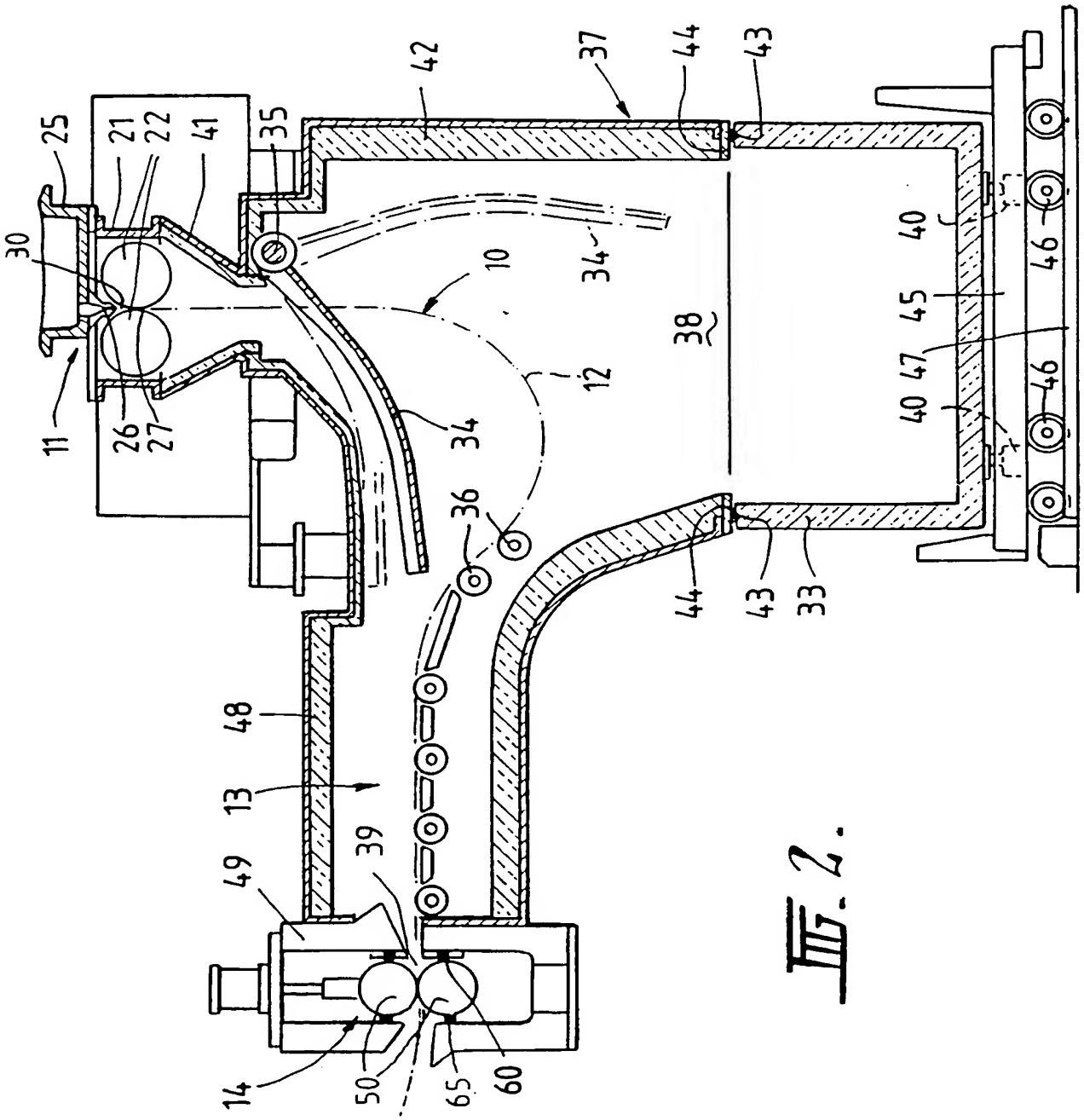

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Fig. 2.

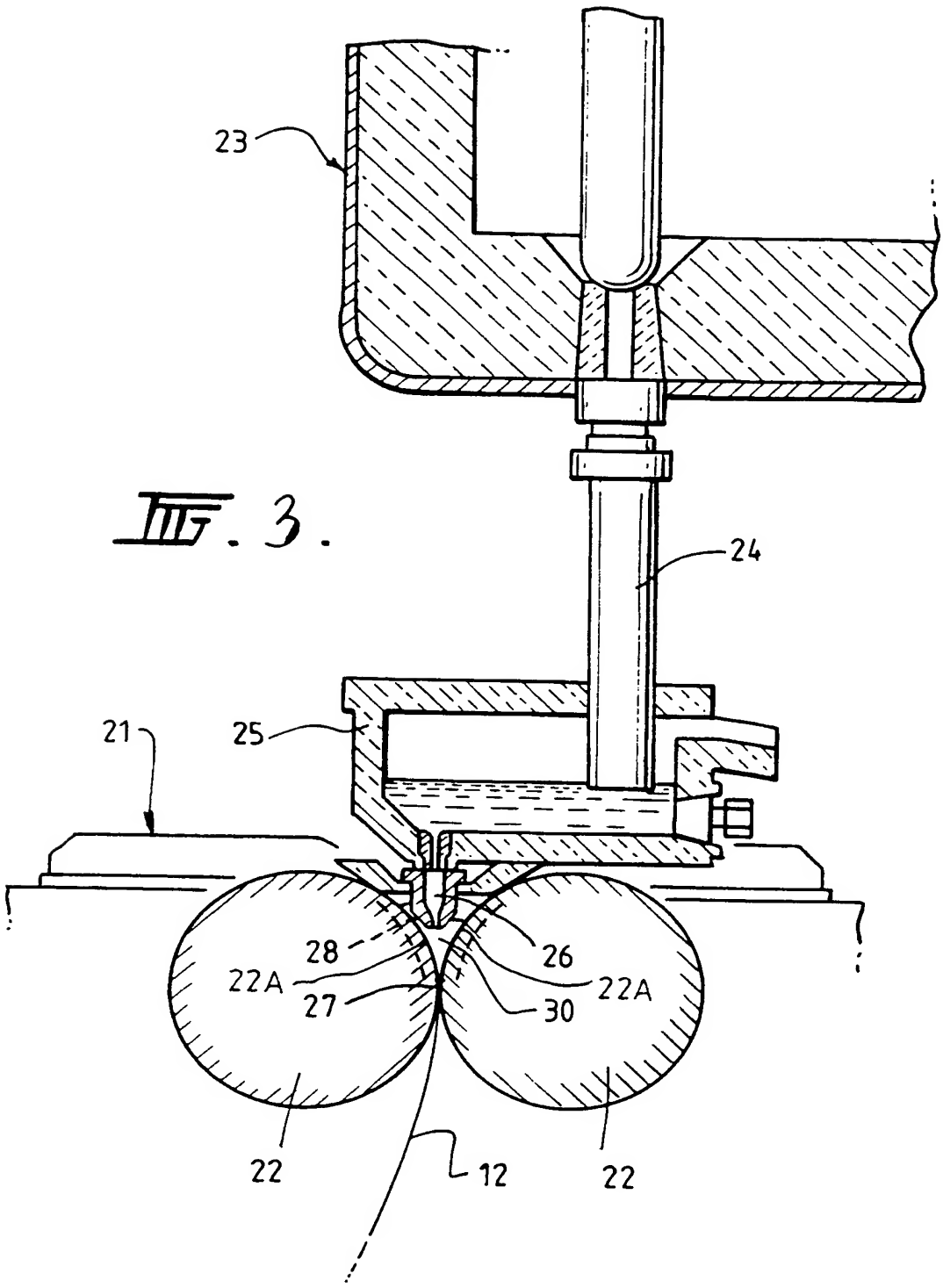

FIG. 3.

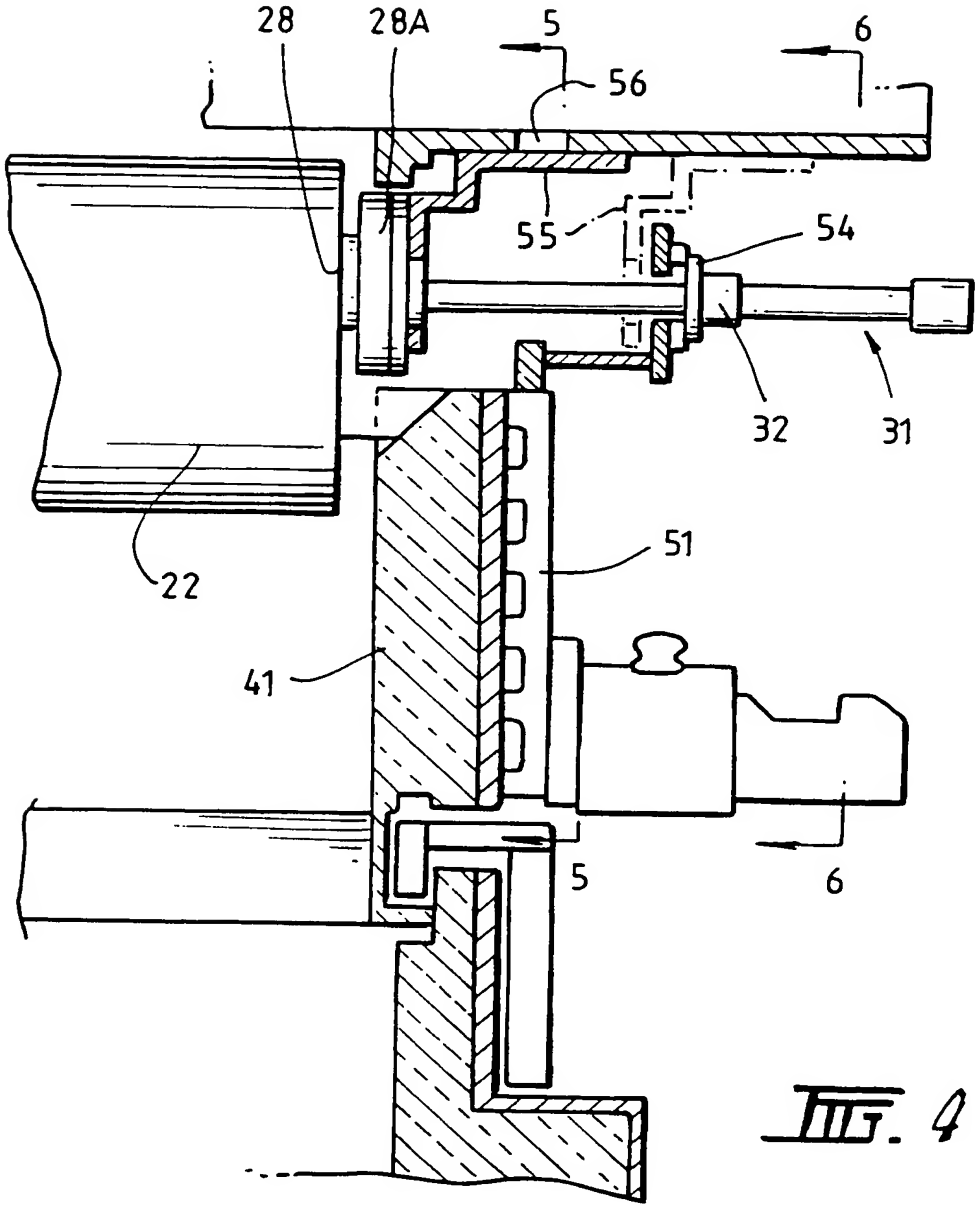

FIG. 4.

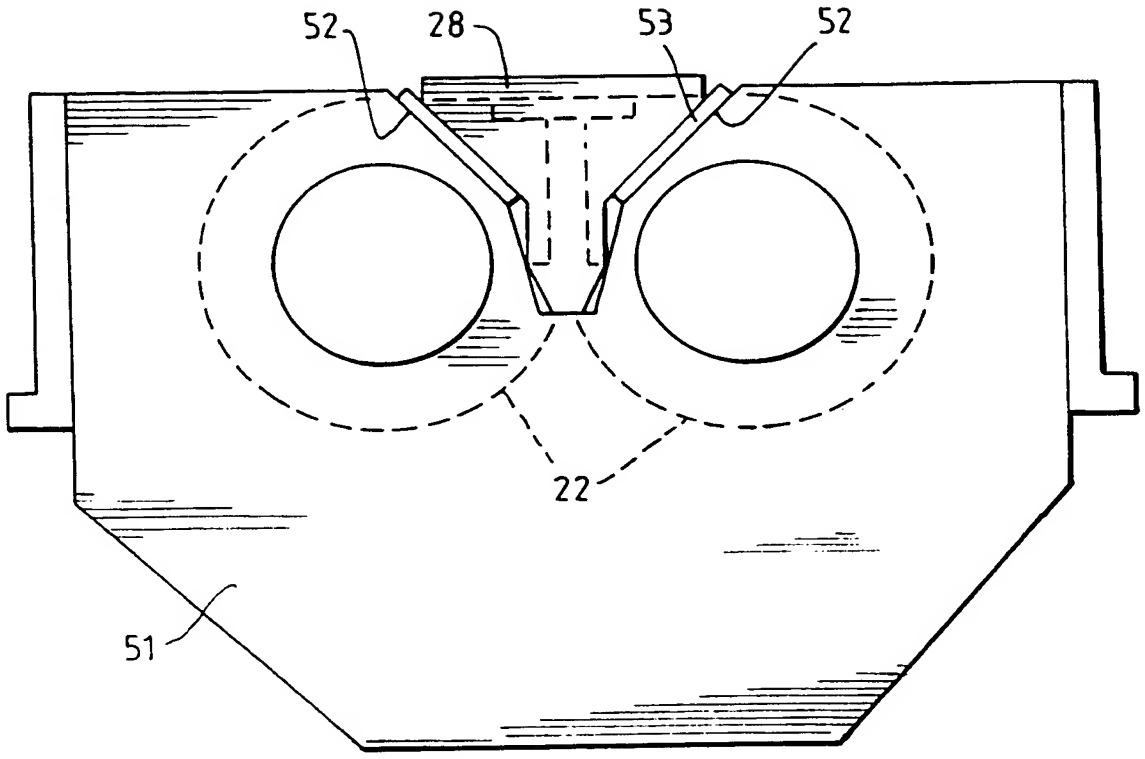

FIG. 5.

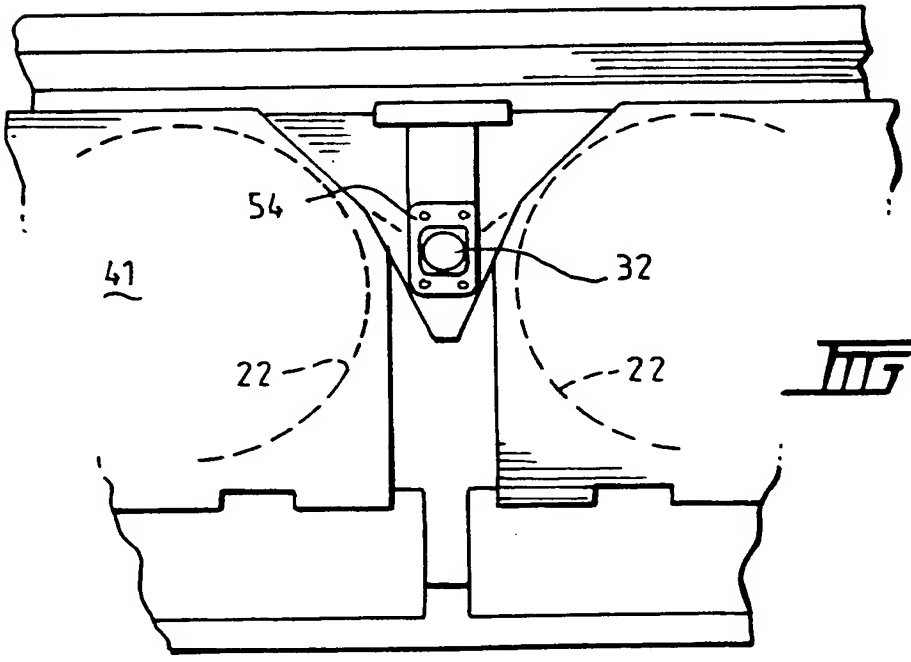

FIG. 6.

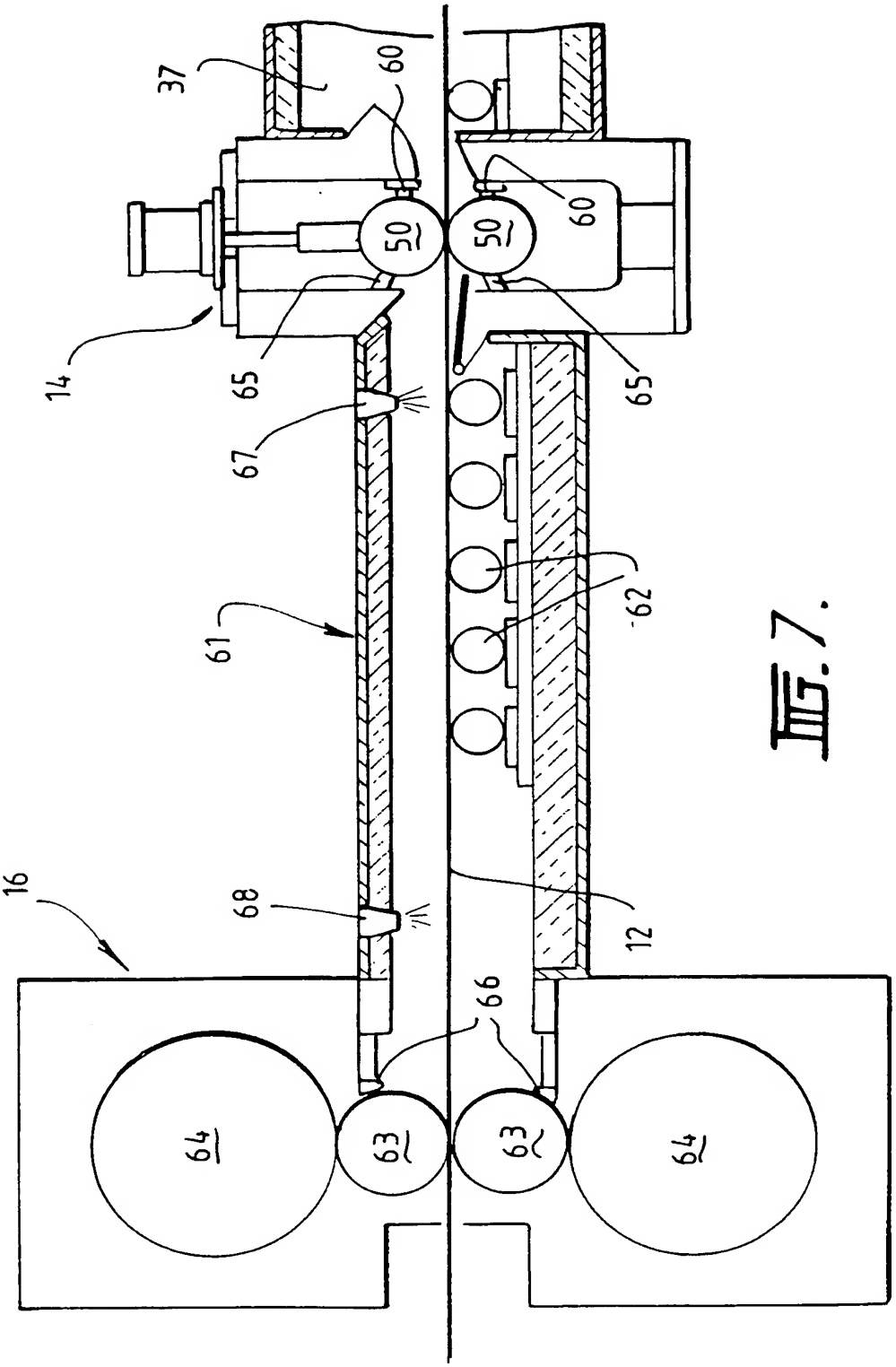

FIG. 7.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 00/01478

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[7]: B22D 011/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B22D 0/11/IC + KEYWORDS

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: B22D 011/06, 011/04

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Derwent

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4658882 A (OBA et al) 21 April 1987	1-24
A	US 5904204 A (TERAOKA et al) 18 May 1999	1-24

☐ Further documents are listed in the continuation of Box C

☒ See patent family annex

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"&" document member of the same patent family

Date of the actual completion of the international search
11 January 2001

Date of mailing of the international search report
1 February 2001

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU 00/01478

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4658882	JP	57122248				
US	5904204	BR	9606325	CA	2192834	CN	1150825
		EP	760397	JP	7331330	WO	9632507
		JP	9029395	ZA	9602970		

END OF ANNEX